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Reduced muscular strength among Canadians aged 60 to 79: Canadian Health Measures Survey, 2007 to 2013

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Abstract

Background: Reduced muscular strength is associated with an increased risk of all-cause, cardiovascular and non-cardiovascular mortality, heart attack, and stroke. At older ages, reduced strength is associated with impaired mobility, risk of falls, and disability. Various criteria are used to determine reduced strength.

Data and methods: Data on grip strength among 3,181 respondents aged 60 to 79 from the 2007 to 2013 Canadian Health Measures Survey were used to calculate the prevalence of reduced strength based on sex-specific percentile and t-score cut-points and cut-points of the Foundation for the National Institutes of Health. Logistic regression was used to identify significant associations between reduced strength and mobility, disability and self-rated health.

Results: Based on stricter criteria, the prevalence of reduced strength among household residents aged 60 to 79 ranged from 3% to 5%; based on less strict criteria, the prevalence ranged from 10% to 18%. Compared with people with normal strength, those with reduced strength had higher odds of impaired mobility (ranging from 3.40 to 8.33, depending on the cut-point), poor or fair self-rated health (2.19 to 4.20), and moderate-to-severe disability (2.21 to 2.60).

Interpretation: Estimates of the prevalence of reduced grip strength varied by cut-point. Reduced strength was significantly associated with impaired mobility, moderate-to-severe disability, and poor or fair self-rated health. Further research is required to determine if associations between reduced strength and other health outcomes vary by cut-point.

Key words: Grip strength, muscle weakness, reduced muscle strength, sarcopenia

Reduced muscular strength has been associated with an increased risk of all-cause, cardiovascular and non-cardiovascular mortality, heart attack, and stroke.[1] At older ages, reduced strength is associated with impaired mobility,[2] risk of falls,[3] disability,[4] and lower health-related quality of life.[5]

Because grip strength is strongly reflective of total body strength,[6] it is commonly used as an indicator of overall muscular strength.[7] Various grip strength cut-points have been proposed to identify those with low strength.

The Foundation for the National Institutes of Health (FNIH) Sarcopenia Project examined associations between grip strength and impaired mobility (gait speed less than 0.8 metres per second), and used Classification and Regression Tree (CART) analysis to develop cut-points to classify people as having weak, intermediate or normal strength.[2] Receiver Operating Characteristics (ROC) analysis has been used to develop cut-points based on an increased likelihood of impaired mobility, defined as difficulty walking half a kilometre or climbing stairs,[8] gait speed less than 0.8 metres per second, or inability to walk 1 kilometre.[9]

The 5th percentile of grip strength of a healthy population has been proposed as a cut-point to identify muscular weakness.[10] This approach is similar to the use of percentiles on growth charts for height, weight and body mass index.[11-13] Others have suggested that t-scores or a specified number (1.0 to 2.5) of standard deviations (SD) below the mean for a younger, healthy reference group could be used.[7,14-16] This approach follows the use of t-scores to diagnosis osteoporosis based on bone mineral density.[17] However, the clinical and prognostic value of these grip strength cut-points has not been determined.

This study compares the prevalence of reduced muscular strength among Canadians aged 60 to 79 based on percentile, t-score and FNIH grip strength cut-points, and examines associations between reduced strength and impaired mobility, self-rated health, and disability.

Methods

Canadian Health Measures Survey

The data are from the first three cycles of the Canadian Health Measures Survey (CHMS), an ongoing survey conducted by Statistics Canada in partnership with the Public Health Agency of Canada and Health Canada. The CHMS collects information about the household population to provide comprehensive direct health measures at the national level. Residents of reserves or other Aboriginal settlements, institutions and some remote regions, and full-time members of the Canadian Forces are excluded. More than 96% of the population is represented. Ethics approval for the CHMS was obtained from Health Canada's Research Ethics Board.[18]

The CHMS involves an in-person household interview and a subsequent visit to a mobile examination centre (MEC). The household interview gathers general demographic and socioeconomic data and detailed health, nutrition and lifestyle information. At the MEC, direct physical measurements are taken, including grip strength, height and weight.

Cycle 1 collected information from respondents aged 6 to 79 from March 2007 through February 2009. Cycles 2 and 3 collected information from respondents aged 3 to 79 from August 2009 through November 2011, and from January 2012

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through December 2013, respectively. A total of 16,606 respondents completed the MEC component. After adjustments for the sampling strategy, the final response rate for 60- to 79-year-olds for the three cycles combined was 53.4%. Details about the survey are available at www.statcan.gc.ca/chms and elsewhere.[19-21]

Grip strength

Muscular strength was measured as isometric grip strength—the maximum force that could be generated by squeezing a handgrip dynamometer. Respondents were not eligible for testing if they were younger than 6 or had an acute or chronic condition that would likely make grip strength measurement unsafe for the respondent or the results unreliable or unrepresentative of their usual grip strength. Grip strength was measured twice on each hand (alternating) using a Smedley III handgrip dynamometer (Takei Scientific Instruments, Japan). The testing procedure was based on the *Canadian Physical Activity, Fitness and Lifestyle Approach (CPAFLA), Third Edition*.[22] Maximum grip strength was the maximum score attained (in kilograms), regardless of which hand was tested.

Other measures

Age was self-reported age at the MEC visit. Height was measured to the nearest 0.01 centimetre using a ProScale M150 digital stadiometer (Accurate Technology Inc., Fletcher, USA). Weight was measured to the nearest 0.01 kilogram using a Mettler Toledo VLC with Panther Plus terminal scale (Mettler Toledo Canada, Mississauga, Canada).

To determine self-rated health, respondents were asked, "In general, would you say your health is: excellent, very good, good, fair, or poor?" Respondents were classified as having impaired mobility if they responded "No" when asked, "Are you usually able to walk around the neighbourhood without difficulty and without mechanical support such as braces, a cane or crutches?" Respondents were asked a series of questions to determine their Health Utilities Index Mark III score—an assessment of functional health status in eight domains: vision, hearing, speech, ambulation, dexterity, emotion, cognition, and pain and discomfort.[23] Overall scores were categorized into four levels of disability: none (1.00), mild (0.89 to 0.99), moderate (0.70 to 0.88), and severe (less than 0.70).[24]

Statistical analysis

There were 16,572 respondents eligible to perform grip strength testing. Respondents were excluded from the present analysis if: they were younger than 60 (n = 13,360) or older than 80 (n = 2) at the time of their MEC visit; their grip strength results were outliers based on visual inspection of scatterplots (n = 8); and/or they did not have test results for both hands (n = 135). This left a final study sample of 3,181 (1,534 men and 1,647 women).

Three sets of grip strength cut-points (Table 1) were used to define reduced muscular strength:

1. Age-, sex-, height- and weight-specific values for the 5th and 10th percentiles based on Canadian reference equations[25];

2. Following the approach of Bohannon and Magasi,[7] sex-specific t-scores calculated as 1.5 and 2.0 standard deviations below the mean grip strength of 20- to 39-year-olds based on previously calculated mean and standard deviations[25]; and

3. Sex-specific cut-points proposed by the FNIH[2] to identify people with weak or intermediate strength.

This resulted in two levels of cut-points: more strict (5th percentile, 2.0 SD t-score, and weak) and less strict (10th percentile, 1.5 SD t-score, and intermediate). The CHMS included only general subjective measures of mobility. The criterion validity of these mobility data was not sufficient to develop grip strength cut-points using CART or ROC analysis.

Based on each cut-point, the prevalence of reduced muscular strength was calculated. Logistic regression was used to determine if 60- to 79-year-olds identified as having reduced muscular strength differed significantly from those with normal muscular strength in terms of impaired mobility, self-rated health, and moderate-to-severe disability. For each cut-point and health outcome, an unadjusted model (not shown) and an age- and sex-adjusted model were examined.

Table 1
Grip strength cut-points for classification of reduced muscular strength among older adults, by sex

Grip strength cut-point	Source	Age	Cut-point value (kilograms)	
			Men	Women
Weak	Foundation for the National Institutes of Health[2]	60 to 79	26.0	16.0
2.0 SD t-score	2007 to 2013 Canadian Health Measures Survey	60 to 79	27.9	16.4
5th percentile	2007 to 2013 Canadian Health Measures Survey	60	32.9	19.3
		79	18.8	12.2
Intermediate	Foundation for the National Institutes of Health[2]	60 to 79	32.0	20.0
1.5 SD t-score	2007 to 2013 Canadian Health Measures Survey	60 to 79	33.1	19.4
10th percentile	2007 to 2013 Canadian Health Measures Survey	60	35.8	21.0
		79	22.7	14.8

SD = standard deviation

All estimates were based on weighted data. Survey weights for combining cycles 1, 2 and 3 were used. Statistical analyses were performed with SAS and SUDAAN software. Standard errors, coefficients of variation and 95% confidence intervals were calculated with the bootstrap technique.[26,27] The number of degrees of freedom was specified as 35 to account for the CHMS sample design.[28]

Results

The grip strength of household residents aged 60 to 79 differed by sex. Women's mean grip strength was significantly lower than that of men: 23.7 kg versus 40.4 kg (Table 2). For both sexes, mean grip strength decreased with age—70- to 79-year-olds had significantly lower grip strength than did 60- to 69-year-olds.

Depending on the criteria with which grip strength was measured, the prevalence of reduced muscular strength varied. Based on the stricter criteria (5th percentile, 2.0 SD t-score, and weak), the percentage of 60- to 79-year-olds with reduced strength ranged from 3% to 5%; based on less strict (10th percentile, 1.5 SD t-score, and intermediate) criteria, the range was from 10% to 18% (Table 3). According to the FNIH and t-score cut-points, reduced strength was significantly more prevalent at ages 70 to 79 than at ages 60 to 69. However, based on the percentile cut-points, the opposite was true.

The prevalence of reduced strength generally did not differ significantly between men and women. The exception was the intermediate cut-point for those aged 60 to 69, according to which an estimated 12% of women, compared with 7% of men, had reduced strength.

The age group composition of 60- to 79-year-olds with reduced strength depended on the cut-points (Figure 1). Based on the percentile cut-points, fewer 70- to 79-year-olds than 60- to 69-year-olds had reduced strength. By contrast, based on the t-scores and FNIH cut-points, 70- to 79-year-olds outnumbered 60- to 69-year-olds among those with reduced grip strength.

Table 2
Mean and percentile of maximum grip strength, by sex and age group, household population aged 60 to 79, Canada excluding territories, 2007 to 2013

Sex and age group	Mean (kilograms)	95% confidence interval		Percentile (kilograms)						
		from	to	5th	10th	25th	50th	75th	90th	95th
Men										
60 to 79	40.4	39.7	41.2	27.4	30.0	34.6	40.0	45.3	50.4	52.6
60 to 69	42.1	41.3	42.9	29.8	31.9	36.7	41.5	46.4	51.6	54.2
70 to 79	36.9†	36.1	37.8	24.6†	27.2†	31.7†	36.7†	41.4†	45.9†	49.0†
Women										
60 to 79	23.7†	23.4	24.1	15.7†	17.4†	20.0†	23.1†	26.2†	29.3†	31.0†
60 to 69	24.6†	24.2	25.0	16.5†	18.3†	21.2†	24.1†	27.1†	29.8†	31.7†
70 to 79	22.1†‡	21.6	22.7	14.3†‡	16.3†‡	18.6†‡	21.6†‡	24.5†‡	27.4†‡	29.4†‡

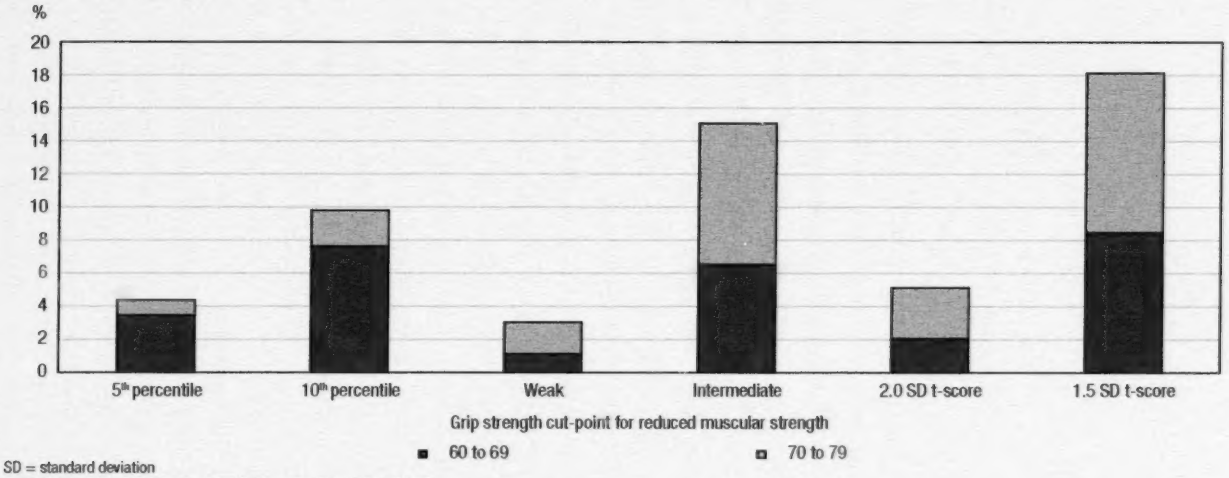
† significantly different from 60- to 69-year-olds ($p < 0.05$)
‡ significantly different from men ($p < 0.05$)
Source: 2007 to 2013 Canadian Health Measures Survey (combined).

Table 3
Prevalence of reduced muscular strength, by sex, grip strength cut-point and age group, household population aged 60 to 79, Canada excluding territories, 2007 to 2013

Grip strength cut-point and age group	Total			Men			Women		
	%	95% confidence interval		%	95% confidence interval		%	95% confidence interval	
		from	to		from	to		from	to
5th percentile									
60 to 79	4.4	3.3	5.8	4.3‡	3.0	6.1	4.4‡	3.0	6.5
60 to 69	5.2	3.9	6.9	4.9‡	3.3	7.2	5.5	4.0	7.5
70 to 79	2.7†‡	1.5	5.1	3.1‡	1.6	5.9	F	...	...
10th percentile									
60 to 79	9.8	8.3	11.6	8.4	6.5	10.9	11.1	9.0	13.6
60 to 69	11.5	9.4	13.8	10.2	7.8	13.2	12.6	10.1	15.8
70 to 79	6.5†‡	4.5	9.4	4.7†‡	2.9	7.8	8.1‡	5.0	12.8
Weak									
60 to 79	3.1‡	2.1	4.3	2.7‡	1.7	4.1	3.4‡	2.2	5.4
60 to 69	1.7‡	1.1	2.6	1.4‡	0.8	2.5	2.0‡	1.1	3.4
70 to 79	5.7†‡	3.8	8.7	5.2†‡	3.2	8.4	6.2†‡	3.3	11.5
Intermediate									
60 to 79	15.1	13.1	17.3	12.3	9.8	15.3	17.6†	15.1	20.5
60 to 69	9.8	7.7	12.4	7.1‡	4.9	10.1	12.4†	9.8	15.6
70 to 79	25.6†	22.2	29.3	23.2†	18.4	28.9	27.6†	23.1	32.6
2.0 SD t-score									
60 to 79	5.1	4.1	6.4	4.5	3.4	6.0	5.7	4.3	7.5
60 to 69	3.1‡	2.2	4.4	2.2‡	1.4	3.5	3.9‡	2.6	6.1
70 to 79	9.2†	6.9	12.2	9.4†	6.8	13.0	9.0†‡	5.9	13.5
1.5 SD t-score									
60 to 79	18.1	16.1	20.4	18.7	15.9	21.9	17.6	15.1	20.5
60 to 69	12.7	10.3	15.5	13.0	9.9	16.9	12.4	9.8	15.6
70 to 79	29.0†	25.5	32.7	30.7†	25.4	36.6	27.6†	23.1	32.6

... not applicable
‡ use with caution
F too unreliable to report
† significantly different from 60- to 69-year-olds ($p < 0.05$)
‡ significantly different from men ($p < 0.01$)
SD = standard deviation
Source: 2007 to 2013 Canadian Health Measures Survey (combined).

Figure 1
Prevalence of reduced muscular strength among household population aged 60 to 79, showing age distribution, Canada excluding territories, 2007 to 2013



SD = standard deviation
Source: 2007 to 2013 Canadian Health Measures Survey (combined).

An estimated 7% of household residents aged 60 to 79 had impaired mobility; 14% had poor or fair self-rated health; and 35% had moderate-to-severe disability (Table 4). The prevalence of each of these health outcomes was significantly higher among people in their seventies than among those in their sixties. A consistent sex difference emerged for impaired mobility, with a higher prevalence among women than men, overall and for each age group.

Results of age- and sex-adjusted logistic regression models show that, compared with 60- to 79-year-olds with normal muscular strength, those with reduced strength had significantly higher odds of having impaired mobility, poor or fair self-rated health, and moderate-to-severe disability (Table 5). The exception was the association with moderate-to-severe disability when the FNIH weak cut-point was used to define reduced strength.

Table 4
Prevalence of impaired mobility, poor or fair self-rated health, and moderate-to-severe disability, by sex and age group, household population aged 60 to 79, Canada excluding territories, 2007 to 2013

	Total			Men			Women		
		95% confidence interval			95% confidence interval			95% confidence interval	
Health outcome and age group	%	from	to	%	from	to	%	from	to
Impaired mobility									
60 to 79	6.8	5.4	8.5	4.4	3.6	5.4	8.9†	6.7	11.7
60 to 69	4.9	3.6	6.7	3.6‡	2.4	5.4	6.2†‡	4.3	8.9
70 to 79	10.4†	7.5	14.2	6.2‡	4.3	9.0	14.0†‡	9.7	19.8
Poor or fair self-rated health									
60 to 79	13.8	12.3	15.5	15.3	13.1	17.8	12.5†	10.7	14.5
60 to 69	11.6	9.9	13.6	13.3	10.8	16.3	10.0	7.9	12.6
70 to 79	18.2†	15.3	21.5	19.5†	15.2	24.7	17.1†	12.9	22.2
Moderate-to-severe disability									
60 to 79	34.7	31.8	37.6	32.2	28.5	36.1	36.9	32.9	41.0
60 to 69	32.5	29.5	35.5	31.1	26.1	36.6	33.7	28.9	38.8
70 to 79	39.1†	33.3	45.2	34.4	28.8	40.6	43.0†	35.1	51.2

† significantly different from 60- to 69-year-olds ($p < 0.05$)
‡ significantly different from men ($p < 0.05$)
E use with caution
Source: 2007 to 2013 Canadian Health Measures Survey (combined).

Discussion

This study presents the first nationally representative estimates, based on various grip strength cut-points, of the prevalence of reduced muscular strength among household residents aged 60 to 79.

The comparability of prevalence estimates of reduced strength depended on the strictness of the grip strength cut-points. At the lower cut-points (5th percentile, 2.0 SD t-score, and weak), prevalence estimates were similar, ranging from 3% to 5%. At the higher cut-points, prevalence estimates based on the 1.5 SD t-score (15%) and intermediate cut-points (18%) were similar; both surpassed the estimate based on the 10th percentile cut-point (10%).

The age distribution of people identified as having reduced muscular strength differed with the cut-point. Among

Table 5
Age- and sex-adjusted odds ratios relating reduced muscular strength to impaired mobility, poor or fair self-rated health, and moderate-to-severe disability, by grip strength cut-point, household population aged 60 to 79, Canada excluding territories, 2007 to 2013

Grip strength cut-point	Impaired mobility			Poor or fair self-rated health			Moderate-to-severe disability		
	Adjusted odds ratio	95% confidence interval		Adjusted odds ratio	95% confidence interval		Adjusted odds ratio	95% confidence interval	
		from	to		from	to		from	to
5th percentile	4.70*	1.69	13.04	2.26*	1.27	4.02	2.50*	1.17	5.33
10th percentile	6.14*	2.91	12.97	2.19*	1.44	3.32	2.60*	1.50	4.49
Weak	8.33*	3.18	21.77	4.20*	1.88	9.37	2.10	0.78	5.64
Intermediate	3.61*	2.25	5.81	2.47*	1.75	3.48	2.38*	1.68	3.37
2.0 SD t-score	5.86*	2.76	12.40	3.19*	1.72	5.93	2.21*	1.04	4.69
1.5 SD t-score	3.40*	2.17	5.34	2.46*	1.80	3.36	2.32*	1.63	3.32

*significantly different from those with normal grip strength ($p < 0.05$)
SD = standard deviation
Source: 2007 to 2013 Canadian Health Measures Survey (combined).

60- to 69-year-olds, prevalence estimates of reduced strength were lower for the weak cut-point compared with the other cut-points. These findings suggest that the weak cut-point for Canadians in this age group is below the 5th percentile.

It is well-established that grip strength peaks in the 30-to-45 age range and declines with advancing age.[16,29,30] This is consistent with the estimates in the present study based on the FNIH and t-score cut-points, but not on the percentile cut-points. In fact, based on the percentile cut-points, fewer 70- to 79-year-olds than 60- to 69-year-olds had reduced muscular strength.

The CHMS estimates of the prevalence of reduced strength based on the FNIH cut-points were consistent with other research using the FNIH cut-points. An estimated 15% of 60- to 79-year-olds in Canada had reduced muscular strength (3% weak, 12% intermediate strength); in the United States, the estimate was 10% (2% weak, 8% intermediate strength).[30] At ages 60 to 69, the present study found a significant difference in the prevalence of intermediate strength for men (7%) compared with women (12%), but estimates did not differ by sex for the other age groups or cut-points examined. In the United States, muscular strength status did not differ by sex at ages 60 to 79, but among those aged 80 or older, the prevalence of reduced strength was higher among women.[30]

People with reduced muscular strength had significantly higher odds of impaired mobility than did people with normal strength. Based on the weak cut-point, the adjusted odds ratio in the present analysis was 3.6; odds ratios of 7.6 for men and 4.4 for women were reported in the United States.[2] Based on the intermediate cut-point, the adjusted odds ratios in the two countries were closer: 3.6 in Canada, compared with 3.6 for men and 2.4 for women in the United States.[2] The discrepancies may be due to differences in definitions of impaired mobility (self-reported ability to walk without difficulty versus measured gait speed less than 0.8 metres per second), populations (Canada versus the United States), and grip strength measurement protocols and equipment.

The odds of reporting poor or fair health were significantly higher among 60- to 79-year-olds with reduced strength than among those with normal strength. Simple, single-item self-assessments of health status, such as the self-rated health question in the CHMS, have been associated with chronic conditions and mortality, independent of numerous health status indicators and other covariates.[31-33] Thus, reduced strength may be an indicator of poor overall health among older adults.

In general, reduced strength was significantly associated with increased odds of moderate-to-severe disability. This is consistent with previous research, which found that people in the lowest midlife grip strength tertile had significantly higher odds of experiencing difficulty with heavy housework, dressing and bathing later in life than did those in the highest grip strength tertile.[4] By contrast, the present analysis did not find a significant association with disability when the weak cut-point was used to classify reduced strength. This may have been due to insufficient power.

The cut-points examined in this study were established using different approaches. The FNIH cut-points were devised to identify clinically relevant weakness and were based on associations with gait speed; the t-score and percentile cut-points were values that were statistically low. Despite the methodological

What is already known on this subject?

- Among older adults, reduced muscular strength is associated with impaired mobility, risk of falls, disability, and mortality.
- Criteria for determining reduced strength vary.

What does this study add?

- Estimates of the prevalence of reduced grip strength at ages 60 to 79 differed by cut-point.
- Reduced strength was significantly associated with impaired mobility, poor or fair self-rated health, and severe-to-moderate disability.
- Research is required to determine if associations between reduced strength and other health outcomes vary by cut-point.

differences, the FNIH and t-score cut-points were similar. The reference group for the t-scores was a younger, healthy population; the reference group for the percentile cut-points was a healthy population of the same age. Both used Canadian reference groups, as previous studies have noted that grip strength differs between countries.[29] Even so, the percentile and t-score cut-points were similar to those derived from data from the United States.[7,34] An advantage of the percentile cut-points is that they can be used across the entire age range, from childhood to older adults, to identify people with reduced strength.

Limitations

Testing position affects grip strength results. The position recommended by the American Society of Hand Therapists (ASHT) requires being seated with the elbow flexed to 90°.[35] Many studies have used this testing position, but many others have not.[29] The CHMS measured grip strength according to the CPAFLA protocol, which requires standing with the elbow extended. This position is consistent with that used in previous national surveys[34,36] and is recommended by the Canadian Society for Exercise Physiology for fitness assessments.[22] Standing yields greater grip strength values than does sitting; results of research on the effect of elbow position are inconsistent.[29]

The CHMS excludes people in long-term residential care facilities and those older than 79, two populations of particular interest when examining reduced strength among older adults. Previous studies have consistently shown that muscular strength decreases with age.[7,16] In 2011/2012, 53% of people aged 80 or older the U.S. household population were found to have reduced strength, compared with 10% of 60- to 79-year-olds.[30] Research that includes people older than 79 and those in long-term residential care facilities is needed to determine the national prevalence of reduced muscular strength.

The overall response rate for cycles 1 to 3 of the CHMS for 60- to 79-year-olds was 54.4%. Although survey weights ensured that the sample was representative of the target population, bias might exist if non-respondents differed systematically from respondents.

Conclusion

Estimates of the prevalence of reduced muscular strength vary by grip strength cut-point. Reduced strength was significantly associated with impaired mobility, poor or fair self-rated health, and moderate-to-severe disability. Further research is required to determine the applicability of these grip strength cut-points to other aspects of health, such as nutritional status. Standardization of cut-points to identify those with reduced muscular strength may facilitate grip strength testing in clinical practice and increase the comparability of research results. ■

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